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SALES hereby certify that annexed is a true copy of the Provisional specification
in connection with Application No. PS 3068 for a patent by WMC RESOURCES
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PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:

"A DATA ACQUISITION UNIT, SYSTEM AND METHOD FOR GEOPHYSICAL DATA"

The invention is described in the following statement:-

A DATA ACQUISITION UNIT, SYSTEM AND
METHOD FOR GEOPHYSICAL DATA

Field of the Invention

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The present invention relates to a data acquisition unit, system and method for geophysical data and, in particular, to such a data acquisition unit, system and method for use in geophysical surveys arranged to measure electric and/or magnetic fields and generate survey data on the basis of the measured field.

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Background of the Invention

It is known to provide a data acquisition system which includes a plurality of networked data acquisition units, each data acquisition unit being connected to at least one sensor

15 and being arranged to gather survey data from the sensors. The received survey data is passed via the network to a central computing device for processing. Synchronisation of the received survey data is also carried out via the network.

However, a disadvantage of this arrangement is that extensive and cumbersome cabling

20 between the nodes themselves and between the nodes and the central computing device is necessary in order to carry out a survey operation.

Summary of the Invention

25 In accordance with a first aspect of the present invention, there is provided a data acquisition unit for geophysical data, the data acquisition unit being connectable to at least one geophysical sensor and arranged to gather geophysical data from the at least one geophysical sensor, and the data acquisition unit including:

processing means arranged to receive the geophysical data gathered by the at

30 least one geophysical sensor connected in use to the data acquisition unit, and to process said received geophysical data so as to generate processed geophysical data of reduced volume relative to said received geophysical data;

time referencing means arranged to generate time reference data usable to control the time at which gathering of geophysical data occurs, and to associate the processed geophysical data with the time reference data;

data storage means for storing said processed geophysical data.

5

Preferably, the data acquisition unit is arranged to gather samples of geophysical data and the time reference data is usable to control the time at which the samples are gathered.

10 Preferably, the time referencing means includes a GPS receiver. Alternatively or in addition, the time referencing means may include an accurate oscillator, preferably a precision oven controlled crystal oscillator, and a counter arranged to count signals generated by the oscillator.

15 In embodiments which include an oscillator, the data acquisition unit is preferably arranged to receive synchronisation signals useable by the processing means to adjust the frequency of the oscillator and adjust the time at which gathering of geophysical data occurs so that the time at which gathering of geophysical data occurs is synchronised with the time at which gathering of geophysical data in other data
20 acquisition units occurs.

Preferably, the data acquisition unit is arranged to receive programs and to store the programs in the data storage means for subsequent execution by the processing means. The stored programs may be arranged to generate processed survey data which is in a
25 more useful format relative to the pre-processed survey data by virtue of attenuation of interference and the reduction in data volume accomplished by the processing. The programs may also be arranged to make decisions in isolation concerning parameters associated with survey data acquisition and processing.

30 Preferably, the data acquisition unit is connectable to an energy source and the data acquisition unit is operable as an energy source control unit. Additionally, the data

acquisition unit can gather energy source output data and the time referencing means is arranged so that these measurements are synchronised with other measurements made by other data acquisition units.

5   Preferably, the data acquisition unit includes at least one interface arranged to facilitate transfer of processed geophysical data and/or programs to or from the data acquisition unit. For this purpose, the interface may include an infra red interface, a serial interface and/or a network interface. The interface may be of a type which utilises wireless protocols, such as Bluetooth.

10

In embodiments which include an oscillator, a synchronisation interface may be provided for facilitating transfer of synchronisation signals to and/or from the data acquisition unit for the purpose of ensuring correct synchronisation of the oscillator with oscillators of other data acquisition units.

15

Preferably, the data acquisition unit includes display means, which may be an LCD display and/or an LED display, arranged to provide information to an operator as to whether operation of the data acquisition unit is satisfactory and/or whether the processed survey data is of sufficient quality for subsequent analysis. Such information
20   may indicate whether there is a fault with the data acquisition unit or with a sensor connected to the data acquisition unit, or whether other conditions exist which necessitate operator action.

Preferably, the data storage means is a FLASH memory. Additionally, a hard disk drive
25   may be provided.

In accordance with a second aspect of the present invention, there is provided a data acquisition system including:
        a plurality of data acquisition units in accordance with the first aspect of the
30   present invention; and
        a plurality of geophysical sensors connected to the data acquisition units, each

said sensor being arranged to sense geophysical signals indicative of a characteristic of a sub-surface volume when the sensor is disposed adjacent the sub-surface volume, and to generate survey data indicative of the geophysical signals.

5   In one arrangement, the system also includes an energy source arranged to generate and direct energy towards the sub-surface volume so as to cause a geophysical response and thereby cause generation of the geophysical signals.

Preferably, the energy source includes a transmitter and a transmitter loop.

10

Preferably, the system also includes an energy source control unit connectable to the energy source and arranged to gather output data from the energy source, the energy source control unit including:

time referencing means arranged to generate time reference data usable to

15   control the time at which gathering of the energy source output data occurs and to associate the energy source output data with the time reference data; and

data storage means for storing the energy source output data.

Preferably, the energy source control unit is a transmitter control unit arranged to

20   control a transmitter so as to energise a transmitter loop in accordance with a predetermined frequency.

Preferably, the energy source control unit includes the same components as the data acquisition unit so that the transmitter control unit is capable of carrying out the

25   functions of the data acquisition unit and vice versa.

In accordance with a third aspect of the present invention, there is provided a method of acquiring geophysical data, said method including the steps of:

providing at least one data acquisition unit arranged to gather geophysical data

30   from at least one geophysical sensor connected in use to the data acquisition unit;

for each data acquisition unit, connecting at least one geophysical sensor to the

data acquisition unit;

processing at the data acquisition unit geophysical data gathered by the at least one geophysical sensor connected in use to the data acquisition unit so as to generate processed geophysical data of reduced volume relative to said received geophysical data;

generating at the data acquisition unit time reference data usable to control the time at which gathering of geophysical data occurs;

associating the processed geophysical data with the time reference data; and

storing said processed geophysical data at the data acquisition unit.

Preferably, the time referencing means includes a GPS receiver. Alternatively or in addition, the time referencing means may include an oscillator, preferably , a precision oven controlled crystal oscillator, and a counter arranged to count signals generated by oscillator.

In embodiments which include an oscillator, the method preferably includes the step of receiving at the data acquisition unit synchronisation signals useable by the processing means to adjust the frequency of the oscillator and thereby adjust the time at which gathering of geophysical data occurs so that the time at which gathering of geophysical data occurs is synchronised with the time at which gathering of geophysical data occurs in other data acquisition units.

Preferably, the method further includes the steps of receiving programs at the data acquisition unit and storing the programs in the data storage means for subsequent execution by the processing means. The stored programs may be arranged to generate processed survey data which is in a more useful format relative to the pre-processed survey data by virtue of attenuation of interference and the reduction in data volume accomplished by the processing. The programs may also be arranged to make decisions in isolation concerning parameters associated with survey data acquisition and processing.

Preferably, the method further includes the step of facilitating transfer of processed geophysical data and/or programs to or from the data acquisition unit. For this purpose, the interface may include an infra red interface, a serial interface and/or a network interface.

5

In embodiments which include an oscillator, the method may also include the step of facilitating transfer of synchronisation signals to and/or from the data acquisition unit for the purpose of ensuring correct synchronisation of the oscillator with oscillators of other data acquisition units.

10

Preferably, the method further includes the step of providing display means for providing information to an operator as to whether operation of the data acquisition unit is satisfactory and/or whether the time-stamped processed survey data is of sufficient quality for subsequent analysis. Said information may indicate whether there is a fault

15   with the data acquisition unit or with a sensor connected to the data acquisition unit, or whether other conditions exist which necessitate operator action.

Brief Description of the Drawings

20   The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which;

Figure 1 is a block diagram of a data acquisition system in accordance with an embodiment of the present invention;

Figure 2 is a block diagram of a data acquisition unit in accordance with an

25   embodiment of the present invention;

Figure 3 is a block diagram of a processing and control unit of the data acquisition unit shown in Figure 2;

Figure 4 is a block diagram of an interface unit of the data acquisition unit shown in Figure 2; and

30   Figure 5 is a block diagram of a data acquisition system in accordance with an alternative embodiment of the present invention.

Description of a Preferred Embodiment of the Present Invention

Referring to Figures 1 to 4 of the drawings, in Figure 1 there is shown a data acquisition

5   system 10 for gathering geophysical data during a geophysical survey. In this example, the system 10 is arranged to transmit and sense magnetic fields, although it will be understood that the invention is equally applicable to other geophysical surveys, such as geophysical surveys based on electric fields or seismic measurements.

10   The system 10 includes a source of energy, in this example in the form of a pair of transmitter loops 12, the transmitter loops generating a magnetic field when an electrical current passes through the loops 12. The magnetic field generated by the coils 12 passes into the earth's sub-surface, and changes in the magnetic field are sensed by a plurality of data acquisition units 14 and associated sensors 15 dispersed around the

15   desired area to be surveyed. The sensed magnetic field data is sampled at a predetermined sampling rate and the data samples are stored at the data acquisition unit 14. By analysing the magnetic field data received at the data acquisition units 14, a user is able to obtain an indication as to the characteristics of the desired sub-surface volume.

20   The system 10 also includes an energy source control unit, in this example a transmitter control unit 16, and a transmitter 18, the transmitter control unit 16 being arranged to control the transmitter 18 so as to energise the transmitter loops 12 in accordance with a predetermined frequency. The transmitter control unit 16 also serves to sample the transmitter current at predetermined intervals corresponding to the sampling rate in the

25   data acquisition units 14 and store the transmitter current samples at the transmitter control unit 16.

The data acquisition units 14 are each arranged to generate time reference data indicative of the time at which the survey data is sampled. Likewise, the transmitter

30   control unit 16 is arranged to generate time reference data indicative of the time at which the transmitter current is sampled. The time reference data is used to synchronise

survey data gathered by each data acquisition unit 14 with survey data gathered by other data acquisition units 14 and with the magnetic field generated by the transmitter loops 12.

5   In this example, the transmitter control unit 16 and each data acquisition unit 14 include the same components and, as a consequence, the data acquisition units 14 are able to function as a transmitter control unit 16 and vice versa. For ease of reference, in the following description of embodiments of the invention, the data acquisition units 14 and the transmitter control unit 16 will be referred to as "nodes".

10

However, notwithstanding that the data acquisition units 14 and the transmitter control unit 16 in the following embodiments include the same components, it will be understood that this is not necessarily the case. As an alternative, the data acquisition units 14 and the transmitter control unit 16 may be configured so as to be dedicated to
15   their respective tasks and, as a result, not interchangeable.

The structure of a node 14, 16 is shown in Figure 2.

Each of the nodes 14, 16 includes circuitry 20 and a power source, in this example in the
20   form of a rechargeable battery 22. As an alternative, power may be supplied from an external power source, as indicated by arrow 24.

The circuitry 20 includes a processing and control unit 26 for processing survey data received from sensors connected in use to the node when the node is used as a data
25   acquisition unit 14, for processing transmitter current waveform data received from the transmitter 18 when the node is used as a transmitter control unit 16, and to control and coordinate operation of the node 14, 16. The circuitry 20 also includes an analogue interface unit 28 for interfacing between the processing and control unit 26 and sensors or a transmitter 18 connected in use to the node 14, 16, and a circuit protection unit 30
30   for protecting the analogue interface unit 28 from damage which may occur as a result of large voltage transients from the sensors 15.

The processing and control unit 26 receives signals indicative of timing and location data from a GPS antenna 32, the timing data being used by the processing and control unit 26 to generate time reference data which governs the time at which the survey data

5   or the transmitter current is sampled.

It will be understood that the type of sensors used will depend on the particular type of geophysical survey operation being carried out. In the present example, the sensors are coil-type sensors.

10

The circuitry 20 also includes an input/output interface 36 arranged to facilitate transfer of information between the node 14, 16 and a separate computing device or between two nodes 14, 16. In this example, the input-output interface 36 includes a serial interface for facilitating transfer of synchronisation signals as required to the nodes 14,

15   16, and an infra red interface for facilitating transfer of geophysical survey data or transmitter current data between the node 14, 16 and a separate computing device using infra red radiation. In this example, the infra red interface is an IrDA interface. The input/output interface may also include a network interface (not shown). The input/output interface may as an alternative be of a type which utilises wireless

20   protocols, such as Bluetooth.

The circuitry 20 also includes a transmitter interface 38 for use when the node operates as a transmitter control unit 16. The transmitter interface 38 serves to transfer control instructions to the transmitter 18 and to transfer current waveform data from the

25   transmitter 18 to the processing and control unit 26.

The circuitry 20 also includes an LCD display 40 for displaying to a user information indicative of the status of operation of the node 14, 16, a user control panel 42 for facilitating direct entry of control instructions to the node 14, 16 by a user, and an LED

30   display 44 which serves to indicate to a user the status of the node 14, 16, whether the node 14, 16 has a fault, whether the remaining power in the battery 22 is low, and so on.

As shown more particularly in Figure 3, the processing and control unit 26 includes a processor 46, a GPS receiver 48 in operative communication with the GPS antenna 32 and arranged to generate timing signals using the signals received from the GPS antenna 32, and a timing unit 50 for generating time reference data using the timing signals.

In the case of a data acquisition unit 14, the time reference data is used to control sampling of gathered survey data received from sensors connected in use to the data acquisition unit 14. In the case of a transmitter control unit 16, the time reference data is used to control sampling of the transmitter current. By associating the time reference data with the received survey data and the transmitter current, the system 10 is able to accurately synchronise received survey data with the transmitter current.

The processing and control unit 26 also includes a data storage device 54 arranged to store survey data received from sensors connected to the data acquisition unit 14 or storing transmitter current data received from the transmitter 18, depending on whether the node is a data acquisition unit 14 or a transmitter control unit 16. The data storage device 54 is also used to store programs for controlling operation of the node 14, 16. In the present example, the data storage device 54 is in the form of a FLASH memory

The processor 46 is arranged to control and coordinate all operations in the node 14, 16 in accordance with programs stored in the data storage device 54. It will be understood that the programs may be pre-stored on the data storage device 54 prior to deployment of the nodes on-site, or the programs may be transferred to the nodes as part of the deployment process by connecting a computing device to the node 14, 16 using the input-output interface 36 and transferring the programs to the node 14, 16 for storage on the data storage device 54.

The transferred programs are arranged to cause appropriate time reference data to be generated and associated with the survey data or with the transmitter current data

depending on whether the node operates as a data acquisition unit 14 or a transmitter control unit 16.

In the case of a data acquisition unit 14, the stored programs are also arranged to cause
5   the processor 46 to process survey data received from sensors 15 connected to the data acquisition unit 14 so as to generate processed survey data of reduced volume relative to the received survey data and which is in a more useful format. The processed survey data together with associated time reference data is stored on the data storage device 54. Processing functions may be carried out during and after data acquisition.
10

The stored programs are also arranged to detect the presence of a transient interference event such as an atmospheric discharge (lightning) or a surge on a power transmission line. Software enables a decision to be made as to which data has been affected by the transient interference and, for the data which has been affected, a best guess of the true
15   data for the relevant sample period is generated to replace the affected data.

The stored programs are also arranged to carry out selective tapered stacking as a method of averaging long series of raw data into smaller series in order to reduce the effects of interference and to reduce the data volume. Repetitive signals at the desired
20   frequencies are significantly enhanced at the expense of signals at other frequencies. The contribution to the stacked data by each element of the raw data varies depending on an assessment made by algorithms in the programs as to the quality of the elements. The resultant stacked data has the highest possible signal-to-noise ratio.

25   The stored programs are also arranged to generate and continuously update estimates of the incoming interference from all sources such as power transmission lines, BLF transmitters, atmospheric sources, and so on. If harmonic interference is still detectable after stacking has taken place, the interference can be removed using a digital filter arranged to remove the affected parts of the spectrum and replace the affected spectrum
30   with interpolated error-free spectra.

The stored programs are also arranged so as to detect a drift in relative timing between the node and the transmitter by cross-correlating a measurement at a site with a previous measurement obtained at the time of deployment of the node at the site. Using this detection, timing drift can be corrected.

5

The programs may also cause the processor 46 to make decisions about acquisition and processing settings on the basis of an analysis of the received survey data, to convert waveforms corresponding to the received survey data into the frequency domain using Fourier transform analysis, to carry out deconvolutions in order to remove the effects of
10   various phenomena which may occur during the survey, such as variations in transmitter waveforms and sensor properties, to convert data into meaningful units, and to calculate quality control indicators for use in assessing the quality of the received survey data.

The stored programs may also enable the processor 46 to make decisions in isolation
15   concerning parameters associated with survey data acquisition and processing. For example, the programs may enable the processor 46 to make decisions on the level of gain to apply to received survey data.

Each of the nodes includes a multi-tasking operating system which enables the node to
20   carry out several functions simultaneously. While acquiring data, the node can be interrogated, for example using a hand-held computing device, in order for an operator to carry out quality control of the performance of the node. Interrogation of the nodes can be carried out without interrupting the acquisition and processing of data being performed by the nodes. Operators are able to download from the node any data stored
25   in the data storage device 54, including information indicative of the quality and physical location of any data stored in the data storage device 54. In this example, transfer of data between a node and the hand-held computing device takes place via the infra red interface provided on the node and a corresponding infra red interface provided on the hand-held computing device. The transfer may also take place via the serial
30   interface or via a network interface.

The analogue interface unit 28, shown more particularly in Figure 4, includes circuitry for four different signal channels, each channel including an amplifier 60 which receives survey data from a sensor 15 or from a transmitter 18 depending on whether the node is a data acquisition unit 14 or a transmitter control unit 16. The filtered data is then

5 passed to a low-pass filter 62 and an A/D converter 64, in this example a 24-bit converter.

Control of the amplifiers 60, filters 62 and the A/D converters 64 including clocking for the A/D converters 64, is carried out by the processing and control unit 26.

10

The protection unit 30 includes a separate protection circuit for each channel, each protection circuit serving to protect the circuitry of the analogue interface unit 28 from damage due to large voltage transients which may be present on the signals.

15 The nodes 14, 16 may also be provided with an accurate oscillator, in this example an oven-controlled crystal oscillator (OCXO), useable by the timing unit 50 to generate time reference data when a GPS signal is unavailable. The crystal oscillator produces an accurate frequency signal which is used by the timing unit 50 to generate time reference data. In this example, the time reference data is the output of a counter arranged to

20 count the number of cycles of the signal produced by the crystal oscillator. However, with this arrangement, since each node 14, 16 includes a separate crystal oscillator, if a GPS signal is unavailable it is necessary to periodically synchronise the crystal oscillators with each other during the course of a survey. In practice, this is achieved by providing the transmitter control unit 16 with a high precision crystal oscillator, by

25 providing each data acquisition unit 14 with a precision crystal oscillator, and by periodically connecting each data acquisition unit 14 with the transmitter control unit 16 through the input/output interface 36 so as to compare the frequency of the high precision crystal oscillator with the frequency of the precision oscillator and to compare the phasing the counter in the data acquisition unit with the phasing the counter in the

30 transmitter control unit 16. Any discrepancy between the frequencies and counters is removed by adjusting the frequency of the precision crystal oscillator and by adjusting

the phasing of the counter associated with the precision crystal oscillator.

When a GPS signal is unavailable for an extended period of time of the order of several hours or more, there is a possibility that the timing reference produced by the oscillator will drift. During a survey with an active source, the drift of a node's timing reference relative to the source primary field waveform can be monitored by a node whilst it is positioned at a particular location. The drift is calculated by cross-correlating a measurement at a particular time with a measurement taken at the time of deployment of the node at the location. Since it can be assumed that the drift is caused by a slow loss of synchronisation at the node, the drift can be corrected by modifying the frequency of the oscillator and phasing of the counter associated with the oscillator in accordance with the detected drift.

An example of a data acquisition method for a geophysical electromagnetic (EM) survey using the above embodiment will now be described.

Operators first deploy one or more transmitter loops 12 at a suitable location for energising a desired survey area, and connect the transmitter 18 to a transmitter loop 12. A transmitter control unit 16 is connected to the transmitter 18 in order to control the transmitter 18 and to sample the current flowing through the transmitter loop 12.

Operators then distribute data acquisition units 14 around the desired survey area and connect each data acquisition unit 14 to one or more sensors, in this example coil-type sensors, by connecting the sensors to the inputs of the protection unit 30.

When deployed, the data acquisition units 14 and the transmitter control unit 16 are switched on and programs residing in the data storage device 54 of each data acquisition unit 14 and transmitter control unit 16 commence their tasks of measuring and recording signals and, in the case of the transmitter control unit 16, controlling the transmitter 18. The operators provide information to the data acquisition unit 14 and the transmitter control unit to update the configuration of the units 14, 16 for the particular survey and

the particular tasks to be carried out. In practice, the majority of settings for all units in a survey will be the same. The instructions given to update the configuration of the units 14, 16 include settings of the transmitter frequency, the rate at which processed survey data is to be stored in the data storage device 54, and other settings related to the

5 processing of survey data. Instructions transferred to the units 14, 16 by an operator are transmitted via the input/output interface 36 using a portable computing device.

Using the same portable computing device attached to the input/output interface 36 of a data acquisition unit 14, an operator can view survey data from the data acquisition unit

10 to verify its operation. Additionally, information provided to the operator via the LCD display 40 and the LED display 44 allows the operator to make a rapid assessment of the functioning of the data acquisition unit 14.

When a transmitter loop 12 is operational, a time-varying primary magnetic field is

15 generated which passes through the survey area, including through the prospective sub-surface volume. Electrically conductive elements of the sub-surface volume respond to the primary fields by conducting electric currents. These currents flowing in the sub-surface themselves generate secondary magnetic fields that can be diagnostic of the geology of the sub-surface volume. Coil sensors disposed in the vicinity of the sub-

20 surface volume detect the time-varying primary and secondary fields and generate a voltage that is fed to the analogue interface unit 28 via the protection unit 30 of a data acquisition unit 14. At the analogue interface unit 28, the survey data is amplified, filtered and converted to digital. The processor 46 then processes the survey data in accordance with the processing steps described above in order to increase signal-to-

25 noise ratio and reduce the volume of data.

At pre-determined intervals governed by the programs and settings stored in the data storage device 54, processed survey data is stored in the data storage device 54 of each data acquisition unit 14. In addition to the survey data itself, information about the

30 timing of measurements, the location of sensors and any other settings or information that is needed for processing of the survey data is recorded in the data storage device 54.

During the course of the survey, an operator visits a data acquisition unit 14 for the purpose of confirming correct operation of the units 14, 16. At this time, processed data or other forms of data may be downloaded from the unit via the input/output interface

5   36 to a portable computing device carried by the operator for the purpose of analysing data quality and collating data from the survey.

When the survey has been completed all survey data measuring the responses of sensors and the current transmitted in the transmitter loop 12 is transferred to a portable

10   computing device from the units 14, 16. It will be appreciated that since the received survey data is processed by the processor 46 so as to reduce the volume of survey data, only a relatively small and inexpensive data storage device is required in each data acquisition unit 14 and only a relatively short time is required to collect and collate data from all data acquisition units.

15

It will also be appreciated that since the received survey data is stored at the nodes 14, 16 for subsequent downloading and analysis after completion of the survey, and since the nodes 14, 16 generate time reference data for the received survey data either through GPS or through a local crystal oscillator, the nodes are effectively autonomous, and

20   cumbersome and expensive cabling between the nodes 14 and the central computing device and/or a timing device is not necessary.

A data acquisition system 70 in accordance with an alternative embodiment of the present invention is shown in Figure 5.

25

The alternative system 70 is suitable for use in areas where GPS in not available. Like features are indicated with like reference numerals.

The alternative system 70 includes a roving node 74 which serves to maintain

30   synchronisation between the received survey data and the transmitter 18.

The transmitter control unit 16 and the roving node 74 include a high precision oven-controlled crystal oscillator and each of the data acquisition units 14 include a less expensive precision oven-controlled crystal oscillator.
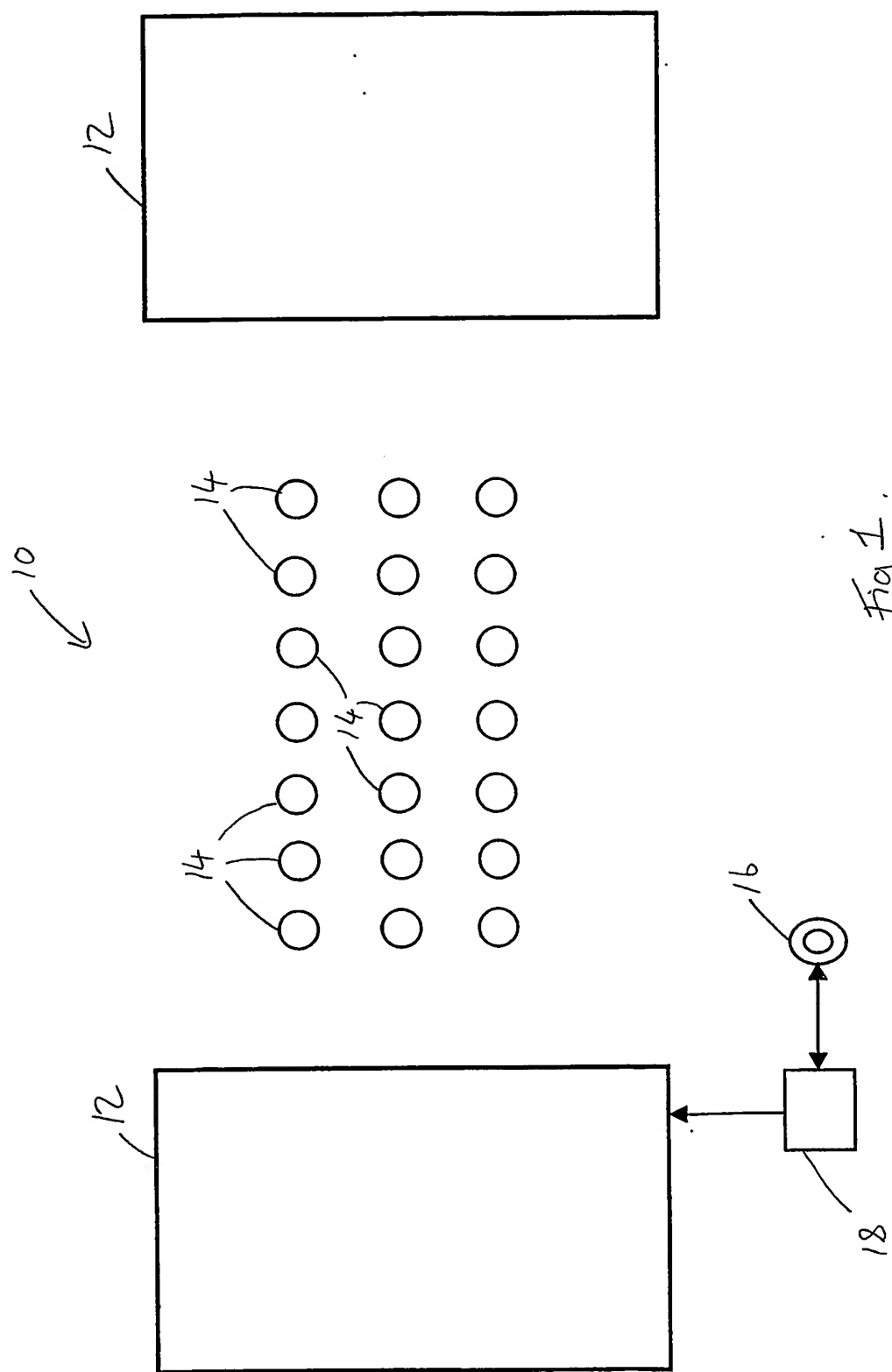
5   In operation, an operator periodically connects the roving node 74 to each data acquisition unit 14 via the input/output interface 36 so as to synchronise the precision crystal oscillators in the data acquisition units 14 with the high precision crystal oscillators in the transmitter control unit 16 of the roving node 74.

10   With this embodiment, instead of the data acquisition units 14 receiving instructions from a portable computing device, the data acquisition units 14 may receive instructions from the roving node 74 when the roving node 74 is connected to the data acquisition units 14.

15   Modifications and variations as would be apparent to a skilled addressee are deemed to be within the scope of the present invention.

DATED this 20th day of JUNE 2002

20   **WMC RESOURCES LTD**

By Its Patent Attorneys
GRIFFITH HACK

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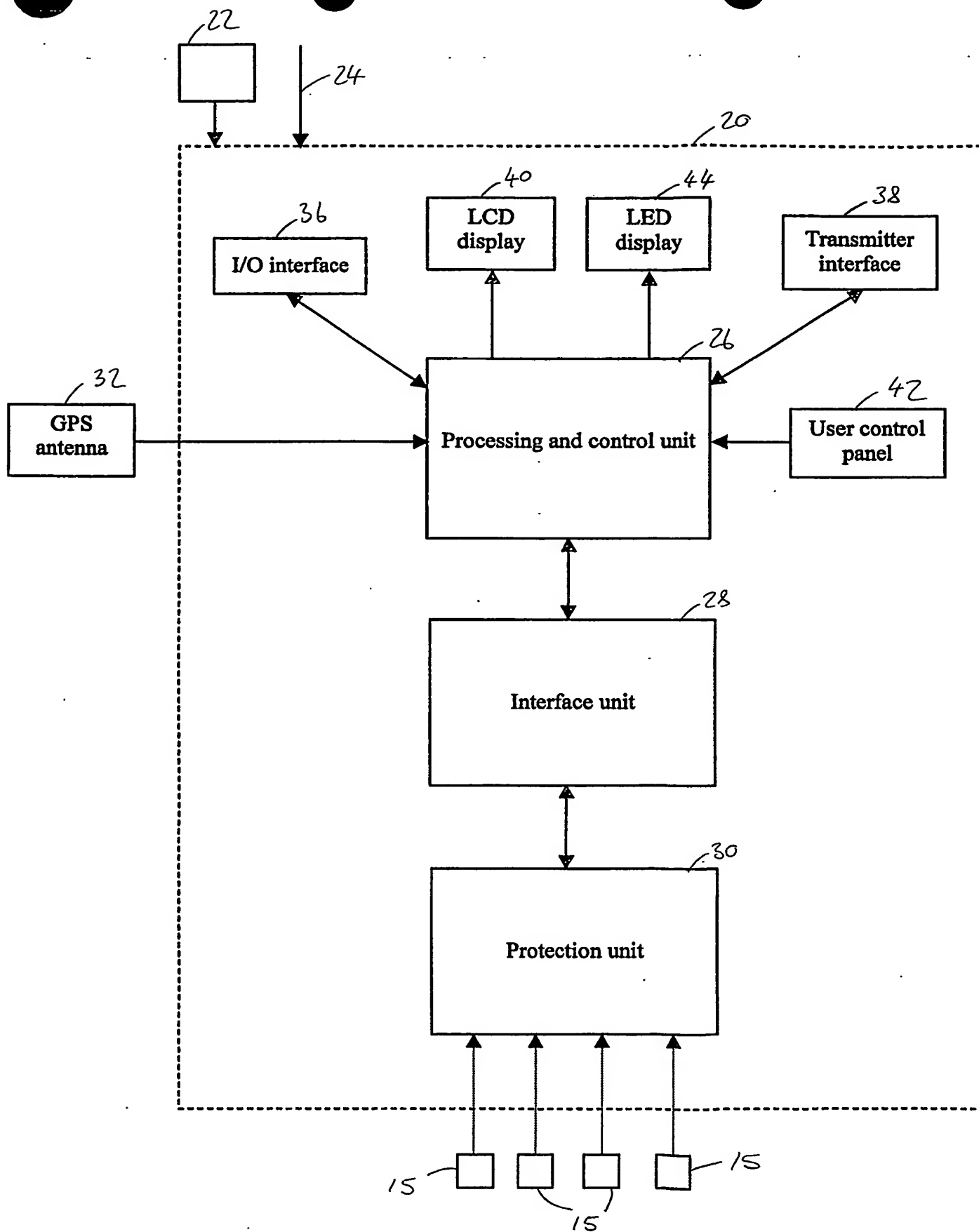Attorneys of Australia
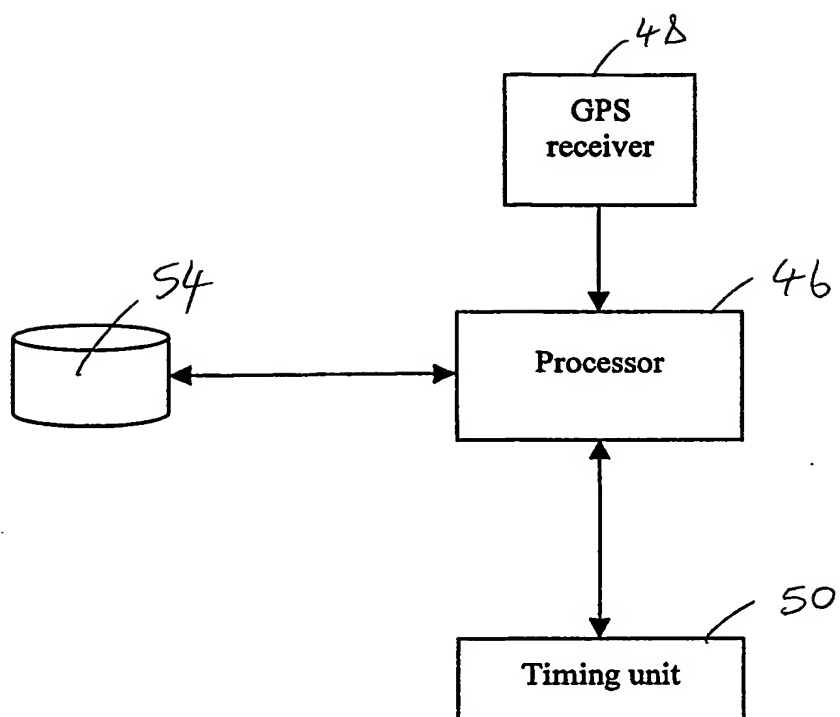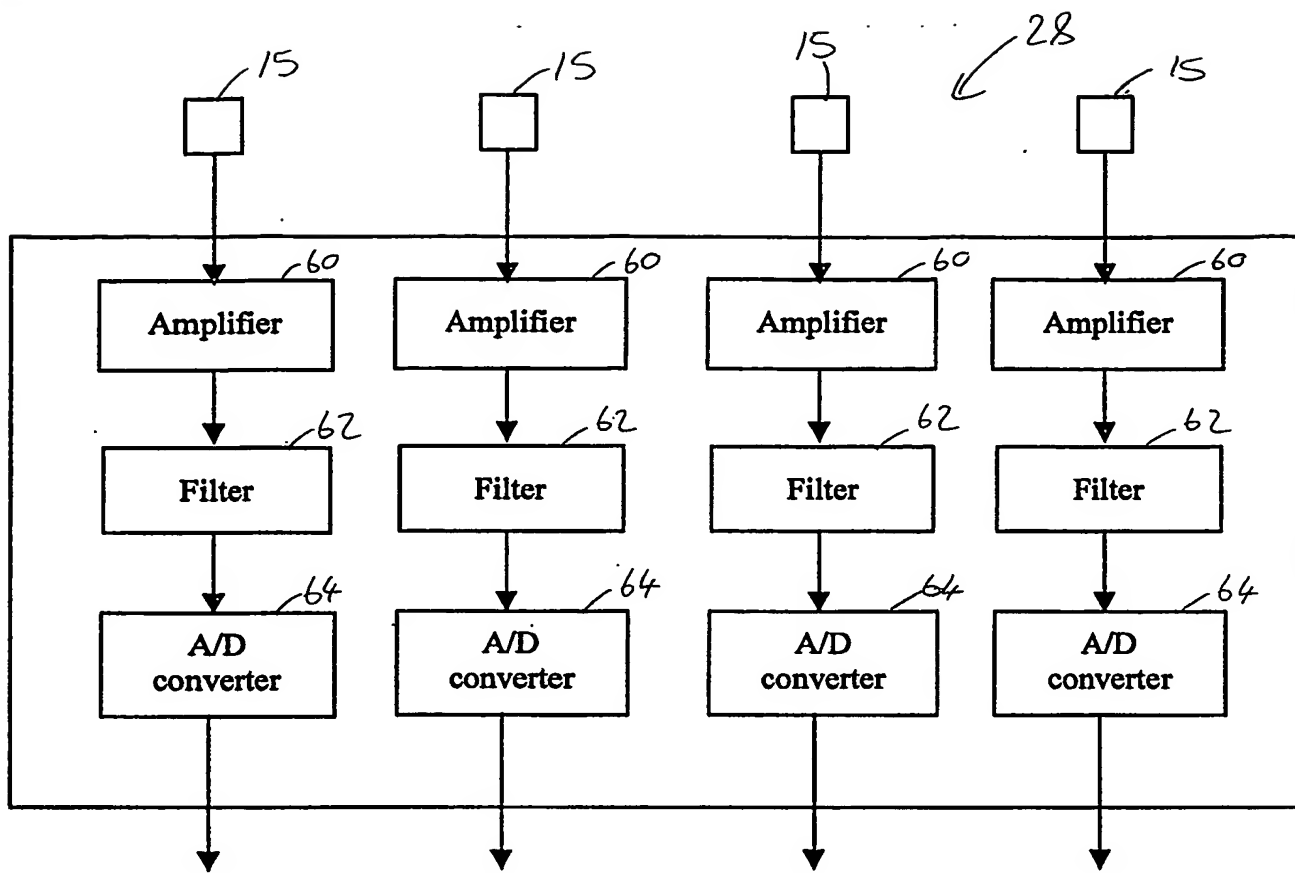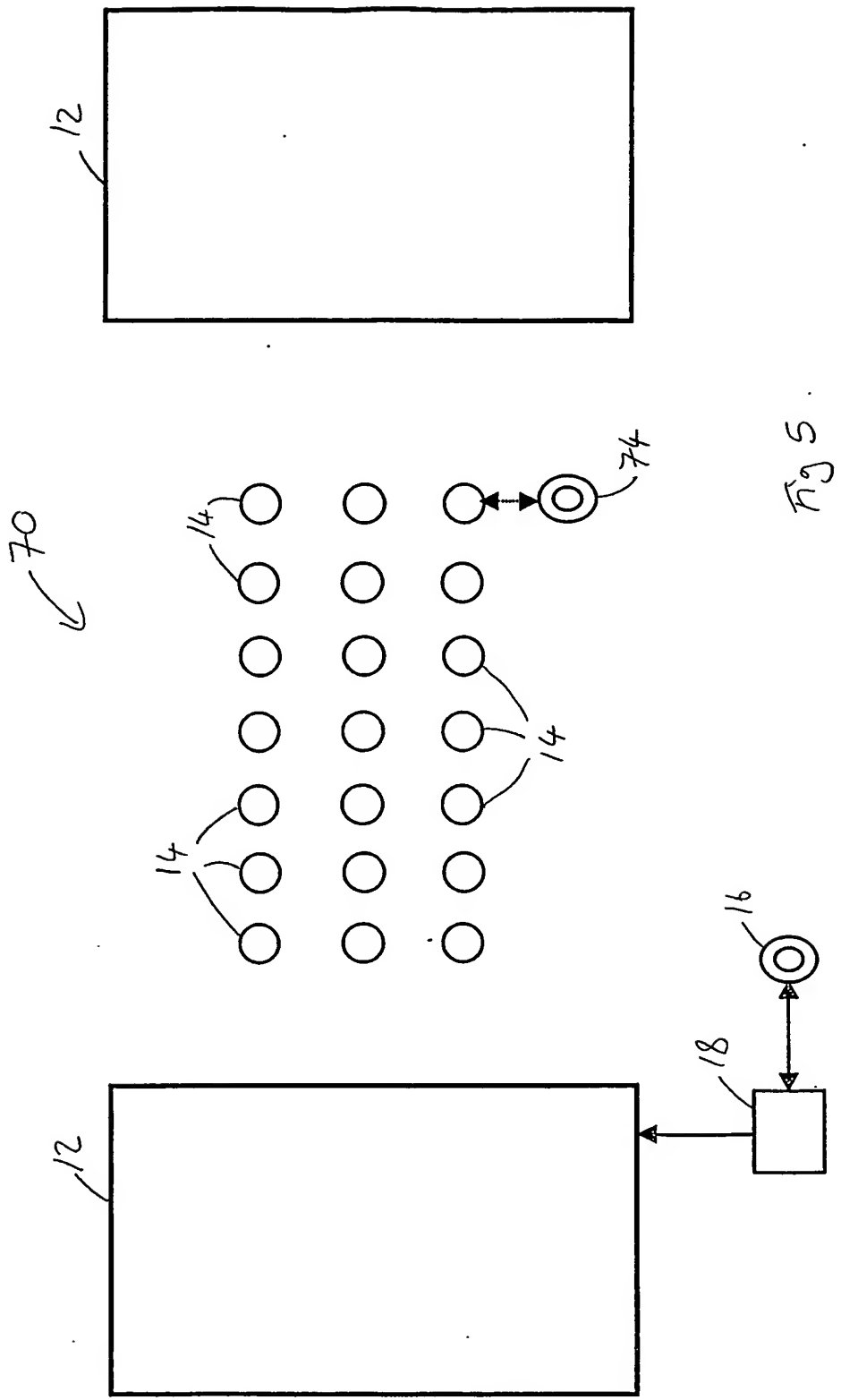
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10

14

14

14

12

16

18

Fig 1.

Fig 2.

48

GPS
receiver

26

54

46

Processor

50

Timing unit

Fig 3

15 28 15 15 15

| Amplifier 60 | Amplifier 60 | Amplifier 60 | Amplifier 60 |

| Filter 62 | Filter 62 | Filter 62 | Filter 62 |

| A/D converter 64 | A/D converter 64 | A/D converter 64 | A/D converter 64 |

Fig 4 .

12

70

14

14

14

74

16

18

12

Fig 5